

# A VIBRATION DAMPER FOR A LOW VELOCITY FOUR GAP ACCELERATING STRUCTURE

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## Abstract

Phase stability of low-velocity superconducting accelerating structures is limited by ambient acoustic noise that excites mechanical vibrations in the cavities. In the ATLAS superconducting ion accelerator, these effects are most troublesome in the heavily loaded very low beta (.008 and .016) four-gap quarter wave resonators. A vibration damper has been designed to reduce such phase noise. This paper reports the performance of a prototype damper that has been implemented in a beta .016 resonator, and tested in operation on-line. Operation has been observed over a period of several months during which the damper has reduced microphonic phase noise by at least a factor of five. It should be noted that this result was obtained despite the fact that the ATLAS operating schedule did not allow time for off-line experimental optimization of the installed damper.

## 1 INTRODUCTION

Low beta superconducting resonators operating below 100 MHz, due to their large size, are affected by low frequency mechanical modes that are easily excited in a normal accelerator environment. The small capacitive gap in the drift tube region of such cavities, needed to obtain a good transit time factor for low velocity particles, transforms even small mechanical displacements into large frequency shifts. Large mechanical vibrations put severe requirements to the rf control system. Residual phase noise, rf power requirements, and operating gradient all strongly depend on the frequency stability of the resonators.

In the 48.5 MHz, 4-gap low beta cavities of ATLAS [1], vibration effects were minimized by careful design, and then compensated by means of a powerful electronic fast tuner [2]. This device is able to compensate frequency excursions of  $\pm 200$  Hz in cavities operating at accelerating gradients of  $\leq 5$  MV/m up to more than 400 Hz. A different approach was followed at Laboratori Nazionali di Legnaro, where 80 MHz, 2 gap resonators, designed for higher particle velocity and appreciably smaller in size and load capacitance, are stabilized by means of internal mechanical damping [3]; a damper was developed which

reduces vibration-induced frequency fluctuations to a few Hz [4].

This paper reports the modification of the Legnaro designed vibration damper for the ATLAS 48.5 MHz very low beta cavities. As a test case for a prototype damper, a particularly troublesome ATLAS cavity (R112) was chosen, which experiences vibration effects causing frequency fluctuations of typically 90% of the available tuning window, and sporadically exceeding the control window. We have designed, built, installed and tested a mechanical damper, with the goal of not only reducing the maximum vibration amplitude of this rather demanding resonator, but also providing a means of reducing residual phase noise in this class of resonator generally.

## 2 MECHANICAL DAMPER DESIGN

The mechanical damper designed for the ATLAS beta=0.016, 4-gap cavity consists of a stainless steel holding tube and a sliding load (Fig.1 and Fig. 2). The load sits on the holding tube terminating disk and it is free to slide over it while being maintained in a coaxial position with the inner conductor by three centering rods.

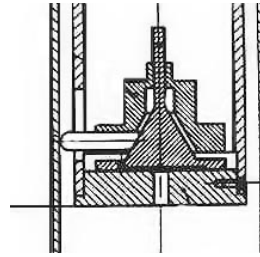


Figure 1. View of the dissipating mechanism with the self-centering load and the terminating disk.

Every displacement of the inner conductor makes the load slide, dissipating mechanical power and reducing the mechanical mode Q. The device is an evolution of the damper developed for the 80 MHz cavities of Legnaro and its parameters have been calculated by means of the technique described in Ref. [5]; the main modification was in the holding tube shape, designed to fit the ANL 4-gap resonator, that was made conical to increase rigidity. Due to the drift-tube structure required by the very low particle

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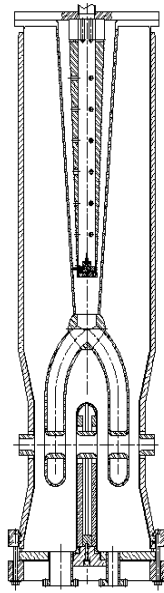


Figure 2. The complete damper installed in the 4-gap cavity.

velocity, the ANL cavity is considerably heavier than the LNL,  $\beta=0.055$  one; moreover, the conical structure of its central conductor tends to shift toward the drift tube region the displacement associated with low-frequency mechanical vibrations. Because of this, to provide significant damping it was necessary to locate the sliding load as close as possible to the drift-tubes, deep inside the central conductor. The load mass, in the absence of experimental optimization, was kept conservatively low to guarantee a successful operation of the damper sliding motion. We wanted to avoid large common mode oscillations of the inner conductor and holding tube, which are strongly coupled together at the onset of any oscillation by the static friction between the load and the terminating disk. While results have shown this choice to be a good compromise, it should be noted that an experimentally optimized load could further improve attenuation.

### 3 ON-LINE RESULTS

The average amplitude of frequency fluctuation in resonator R112 was measured, during normal accelerator operation, before installing the mechanical damper. Also, the intrinsic decay time for mechanical vibrations was measured. An adjacent resonator (R113) of the same class (I2) was also monitored, as a reference. The amplitude of frequency fluctuations was determined by monitoring the frequency error signal to the cavity fast-tuner system. After installing the mechanical damper, the frequency noise and the mechanical vibration decay time were measured. The results are shown in Tab.1 and Fig.3. Installation of the mechanical damper changed the mechanical vibration decay time from 28 to 0.5 seconds. Even though non-linear effects in the mechanical damper

complicate the interpretation of these numbers, we have clearly achieved a significant damping, which doesn't allow mechanical excitations to survive for very long.

The average frequency noise of the previously unstable resonator R112 was attenuated by a factor of about 5, and the fast tuner compensation requirements, in the damped cavity, became even lower than in the reference cavity R113. Vibration in this cavity was monitored for 2 months of nearly continuous linac operation; following the damper installation, virtually no loss of lock of the cavity was observed.

Resonator	Frequency Noise (Hz)	Vibration Decay Time (s)
R112 Before damper installation	~375	28
R113 (control cavity)	~125	-
R112 After damper installation	$40 \div 80$	0.5
R113 (control cavity)	$80 \div 125$	-

Table 1. Frequency stability measurement results

## 4 CONCLUSIONS

The frequency fluctuations of a very low-beta superconducting cavity of the ATLAS linac, which are caused by mechanical vibrations excited by environmental acoustic noise, have been substantially reduced by a specially designed mechanical damper. This device reduced significantly the fast tuning system requirements. The experimental results show that mechanical damping of superconducting cavities can be a very effective method of limiting mechanical vibrations in very low beta structures. Combining this technique with electronic fast tuning can reduce residual phase noise, and also extend significantly the possibilities for operating large, low-frequency superconducting cavities at high gradients.

## 5 REFERENCES

- [1] K.W. Shepard, IEEE Trans. Nucl. Sci.(1985) 3574.
- [2] N. Added, B.E. Clift, K.W. Shepard, "UPGRADED PHASE CONTROL SYSTEM FOR SUPERCONDUCTING LOW-VELOCITY ACCELERATING STRUCTURES", Proc. Of the 16<sup>th</sup> Int. Linear Acc. Conf., 1992, Ottawa, Ontario.
- [3] A. Facco, V. Zviagintsev, "MECHANICAL STABILIZATION OF SUPERCONDUCTING LOW BETA RESONATORS", Proc. of the 1999 Particle Accelerator Conf., Vancouver, Canada, 1997.
- [4] A. Facco, V. Zviagintsev, S. Canella, A. Porcellato and F. Scarpa, "ON-LINE PERFORMANCE OF THE LNL MECHANICALLY DAMPED SUPERCONDUCTING LOW-BETA RESONATORS", Proc. of the 1998 European Particle Accelerator Conf., Stockholm, Sweden, 1998.
- [5] A. Facco, "MECHANICAL MODE DAMPING IN SUPERCONDUCTING LOW BETA RESONATORS", Particle Accelerators, vol. 61 (1998) pp. [265-278]/1-14.

Figure 3. Frequency fluctuations in cavity R112 (with mechanical damper) and R113 (without mechanical damper). The dotted line represents the average frequency fluctuation of R112 before the mechanical damper installation.

